Cogging in Fermilab Booster

Evgeniy Koval, NSU

Supervisor: Kiyomi Seiya

Booster

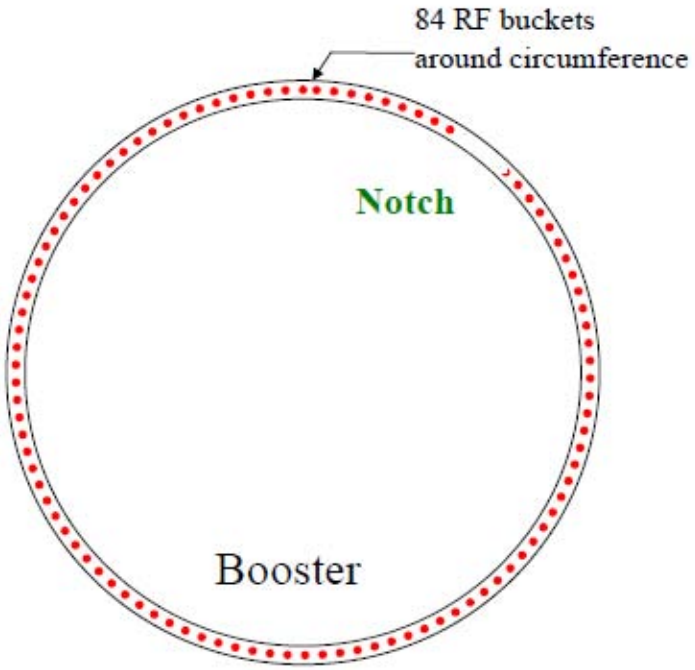
Booster parameters

- Diameter.....150 meters
- Injection energy.....400 Mev (kinetic)
- Extraction energy.....8 Gev (kinetic)
- Cycle time.....33 msec
- Harmonic number, h.....84
- Injection Frequency.....37.77 Mhz
- Extraction Frequency.....52.81 Mhz
- Typical bunch intensity.....5 x 10e10

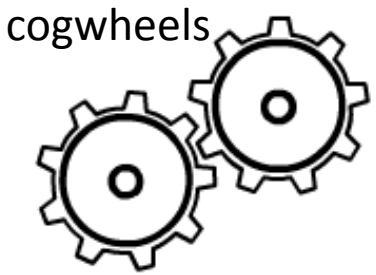
Notching

- Defined:

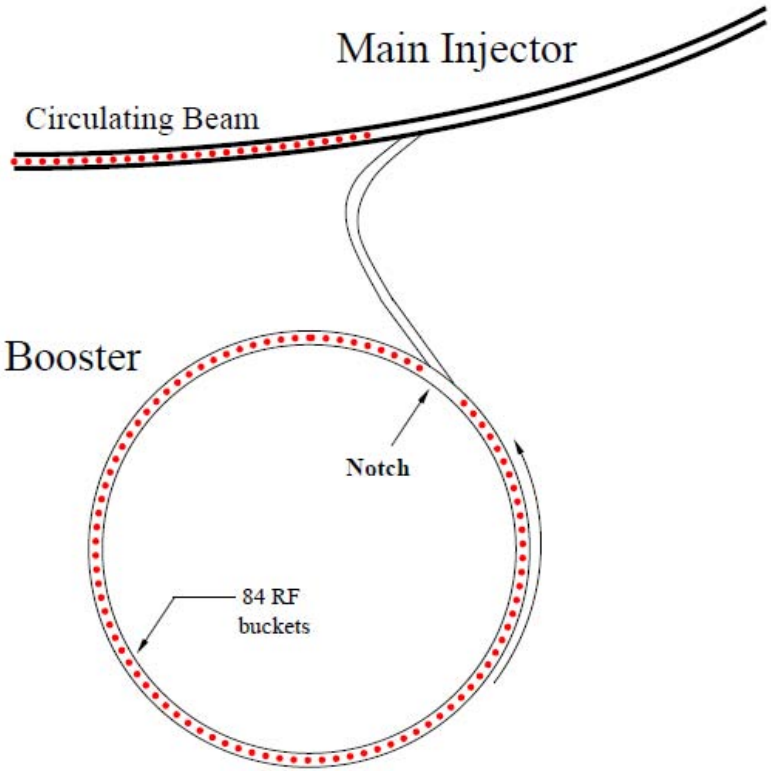
  act of using a dedicated kicker magnet in Booster Period 5 to induce orbit distortion on the last 3 bunches in a batch of Booster beam.



- Extraction kicker risetime ≈ 40 ns.
  - Bunch-to-bunch space at the extraction ≈ 20 ns
- Instead of loosing beam at 8 GeV during extraction beam is removed at 400 MeV
  - Reduces energy loss 20x times



Booster Cogging



- Defined: adjusting the revolution frequency of bunched beam in a synchrotron to correspond to some external frequency

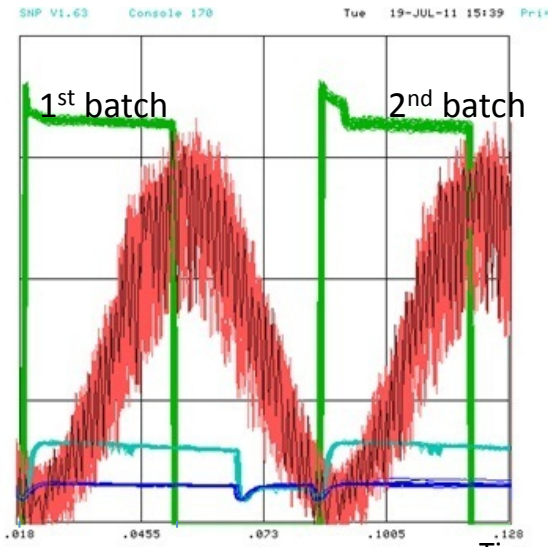
- Extraction:
  - More than 2 batches needed to be extracted to Main Injector
  - Batch in booster should be aligned with the Main Injector beam

- To synchronize Booster and Main Injector procedure to align notch and beam in MI – cogging – is needed.

Current state of “Notching” in Booster

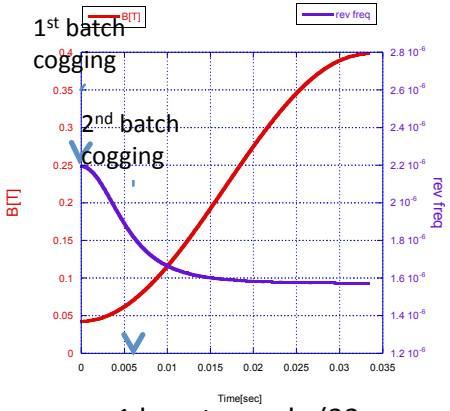
Number of particles in the beam

Magnetic field



Time,sec

1 booster cycle (33 msec)



1 booster cycle (33 msec)

- Notching of the 1st batch is completed as soon as possible:
  - Kicker is synchronized with the beam revolution marker
  - No beam in Main Injector, cogging is not needed for the first batch

- 2nd -7th batches are notched later
  - Cogging is needed to match beam in MI with the beam being extracted from Booster
  - Notch position moves slower when completed on the higher energy (revolution time changes slower when magnetic field is bigger)

The goal of the research:

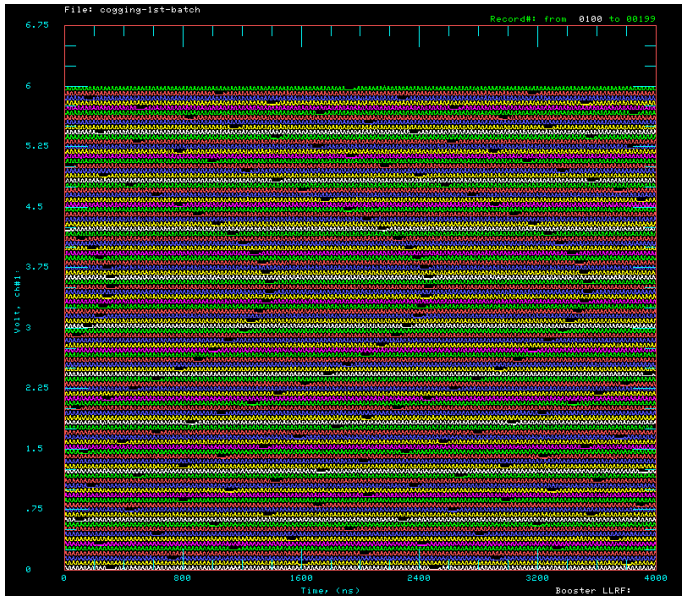
- To decrease energy loss while notching the beam in Booster
- Create notch at lower energy
- Complete cogging with dipole corrector

Task:

1. Get acquainted with longitudinal motion & make simulation
2. Understand the variation of the B field at the injection energy
   - Set up the measurement of the beam signal using wall current monitor
   - Compare experimental results with simulation
   - Calculate total bucket slippage
3. Estimate required B field from dipole corrector

Data acquisition & analisys

Number of trace



Time, nsec

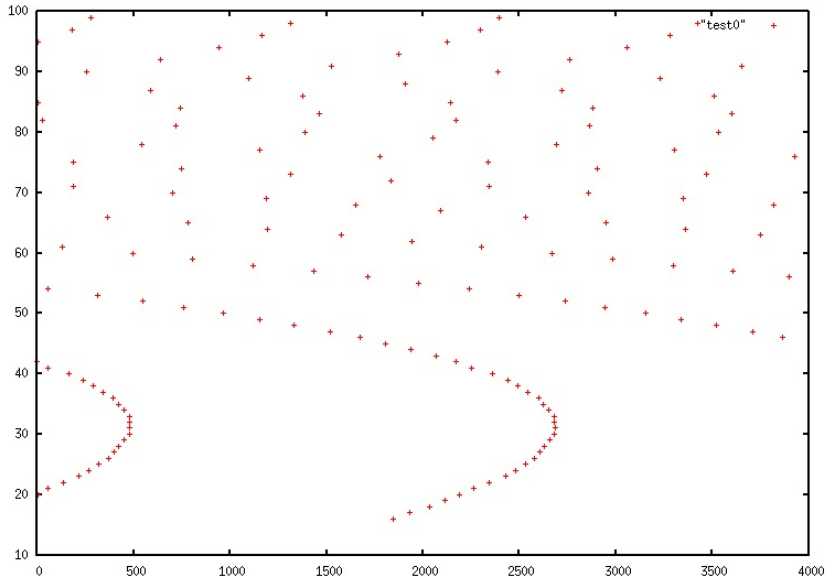
Mountain range plot:

- External trigger starts to collect data with the set frequency
- Data array of the fixed length (10^4 points, 0.4 nsec/point) is taken for each trigger signal
- Different traces are shown on the same plot
- ***Revolution time*** and corresponding ***magnetic field*** can be calculated while comparing distance between “gaps”

Analysis & comparison with simulation

"Gap" position at Mountain range plot

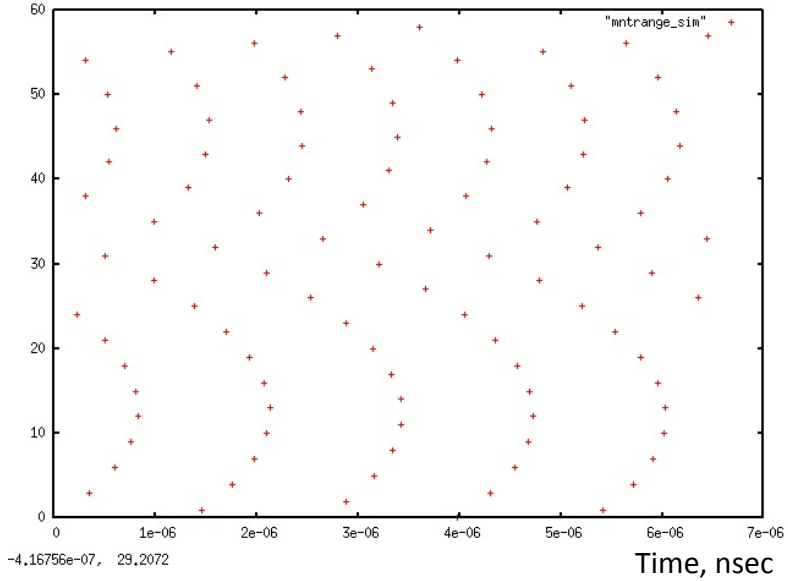
Number of trace



Time, nsec

Measurement

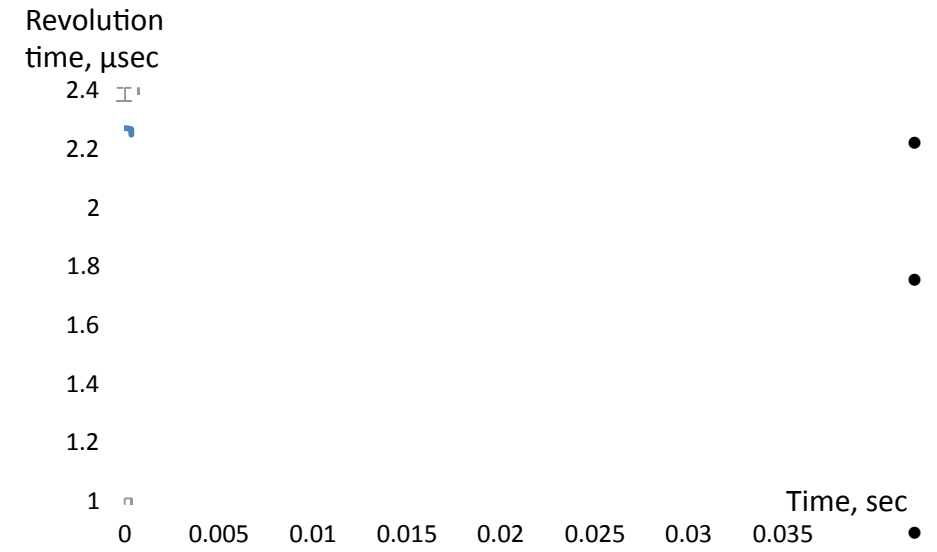
Number of trace

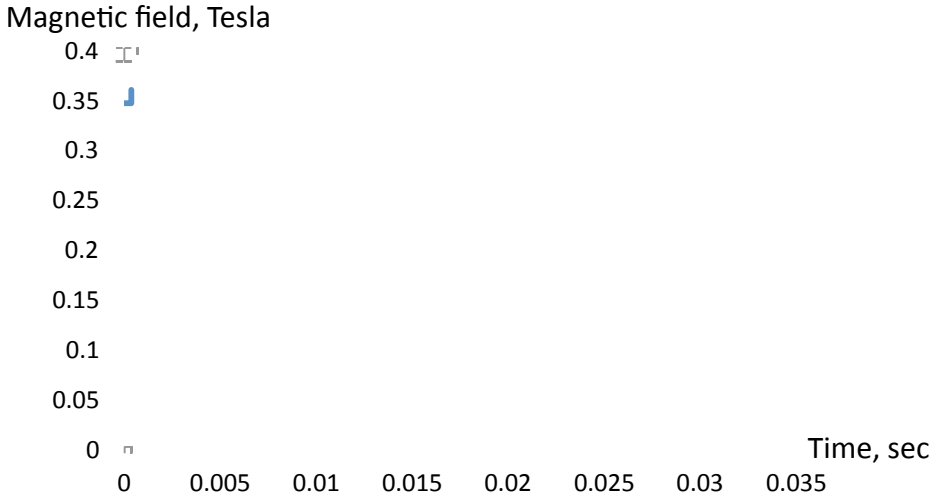


Time, nsec

simulation

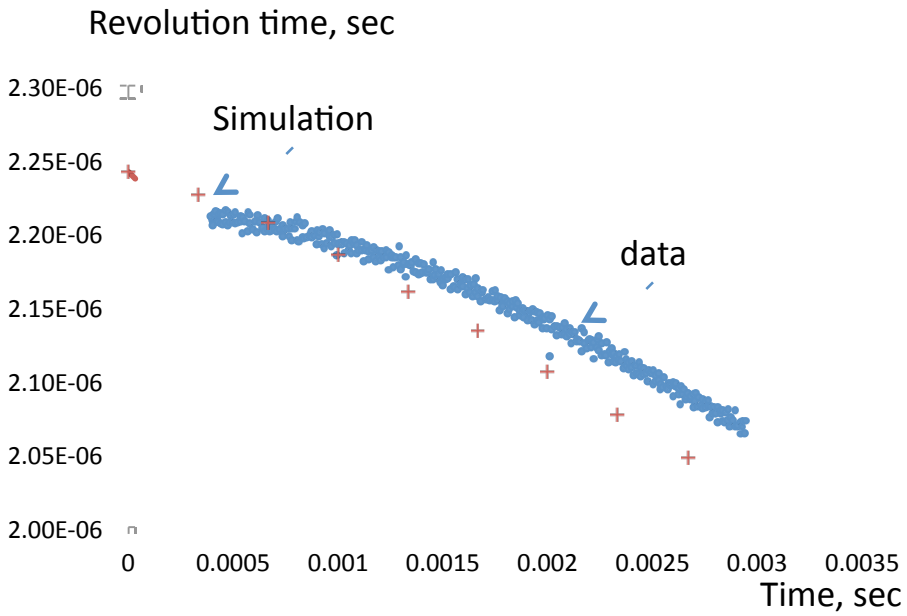
Simulation





- E_{inj}= 400 MeV, $E_{extraction}$= 8GeV
- The magnetic field in Booster is changing as sin with the frequency of 15Hz
- Revolution time during acceleration can be calculated

Preliminary results



- Bucket slippage can be calculated while comparing revolution time of the real beam and simulation

Summary

1. Got acquainted with longitudinal motion & several simulations on it have been completed

2. Understand the variation of the B field at the injection energy

   - set up the measurement of the beam signal using wall current monitor
   - Compare experimental results with simulation

3. Estimate required B field from dipole corrector

Future plans

- Get more data sets to compare with simulation
- Calculate bucket slippage while notching on lower magnetic field values, i.e. lower energies.
- Continue with how calculated magnetic field corrections could be applied to synchronize “gap” position in Booster with existing beam in Main Injector
- To do measurement with dipole corrector